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13. ABSTRACT

This TOP describes general procedures for atmospheric field exposure of materials in a humid tropic environment and for measuring change in physical properties of the materials after exposure. It also describes the various exposure sites available at the U.S. Army Tropic Test Site.

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U.S. ARMY TEST AND EVALUATION COMMAND
TEST OPERATIONS PROCEDURE

*Test Operations Procedure 1-2-616 — 11 November 1994
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TROPIC EXPOSURE TESTING

1. SCOPE. This Test Operations Procedure (TOP) describes general procedures for atmospheric field exposure of materials in a humid tropic environment and for measuring changes in physical properties of the materials after exposure.

2. FACILITIES AND INSTRUMENTATION

2.1 Facilities

a. Exposure Facilities. The United States Army Tropic Test Site (TTS), Fort Clayton, Panama, has a number of sites available for exposure of materials. These sites provide various tropic macro-environments, each one having peculiar conditions that accelerate specific environmental effects. The appropriate exposure site should be selected based on the unique requirements of the test item. A brief description of the general environmental conditions at each site is presented in Appendix C. A number of different micro-environments also may be found at each exposure site. These should be considered when selecting a specific location at the exposure site. Each

*This TOP supersedes TOP 1-2-616, dated 1 May 1980.
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micro-environment will affect the material differently. Therefore, all micro-environments present at any site should be considered at the test planning stage during site selection.

Item	Requirements
Exposure Sites	Materials exposure will be conducted in the natural environment. A suitable exposure site should be selected in the humid tropics based on the expected environmental conditions under which the test item** is intended to be used. Generally, selection of exposure sites should be made in the most severe, yet realistic natural environment available to increase the chances of detecting material problems. Environmental parameters normally considered for site selection are: a. Daily Temperature (high, low, mean) b. Relative Humidity (high, low, mean) c. Rainfall (monthly, daily) d. Vegetation Description (types, stem size, stem density and height) e. Solar Radiation (intensity, wavelength range) f. Soil (type) g. Wind (direction and speed) h. Atmospheric Saltfall [Chloride] (mg [Cl-]/(m^2 · day)) i. Microbial Activity (levels) j. Insect Activity (types and levels)

NOTE: The importance of each of these parameters is discussed in Appendix B.

Laboratory Facility	This facility has a suitable environment for conducting laboratory tests to measure physical properties of test materials. Storage of control material samples is normally accomplished under controlled environmental conditions within the laboratory facility.

**Refers to an individual material specimen.

Item	Requirements
Meteorological Site	Instruments for collecting climatological data during the exposure test should be located in the immediate area of the materials under test. Historical data may provide suitable characterization of meteorological conditions for long term exposure programs.
Exposure Racks	These structures are used to hold the test materials at a specified height and angle of exposure. The racks must be securely anchored for protection against high seasonal winds or tropical storms.
Sample Holders	Most material samples tested will not be suitable for mounting directly on exposure racks. In these cases, sample holders are used to support the test specimens.

b. Exposure Modes. The materials to be tested may be evaluated according to any of the following conditions (or exposure modes) under which the materials are intended to be used or stored.

Mode	Requirements
Direct Exposure	Exposure to all prevailing atmospheric elements.
Open Shed	Exposure under a roofed structure with open sides permitting free air flow but not subject to direct sunlight and rainfall.
Covered	Exposure approximately 10 cm above the ground on a pallet and covered with tarpaulin to exclude direct sunlight and rainfall.
Storehouse	Exposure in a large building, tent, or bunker.

2.2 Instrumentation

a. Field Instruments. The following types of instruments are required

for field inspection and data collection. Accuracy of the instruments will depend upon specific test requirements and should be addressed during test planning with attention given to the maximum permissible errors.

(1) Meteorological Instruments.

<u>Devices for Measuring</u>	<u>Measurement of Accuracy</u>
Temperature	± 2°C
Relative humidity	< 90% ± 1%, ≥ 90%, ± 5%
Rainfall	± 1 mm
Solar radiation	± 5% of cumulative, ± 2% of individual reading
Wind speed	± 5% of observed value
Wind direction straight/steady	± 2°, gusts ± 10°
Air-salt deposition	± 10% of measured value
Ozone, Nitrous Oxide, Hydrocarbons, Sulfur compounds	± 10% of measured value
Ambient light	± 10% of measured value

(2) Miscellaneous Instruments

Sample weight changes	± 0.1% of measured value or as otherwise specified
Visual changes of sample	as specified by the appropriate standard
Distances	± 1/3000 (surveyed) of observed value, ± 2% (vehicular) of observed value
Heading	± [illegible]
Surface analysis	± 10% of measured value
Sample characteristics	as specified by the appropriate standard

Dimensions	± 0.02 mm, 0.1% of measured value, or as specified
Durability	± 5% of expected service life
Color	± 1 color chart division

b. Laboratory Instruments. The selected procedures for measurement of material characteristics (paragraph 3.1.d) will determine the required laboratory instruments for the exposure test. The required accuracy of the instruments usually will be given by selected standard procedures (e.g., American Society for Testing and Materials (ASTM) standards or Federal Test Method standards) and should be addressed during test planning.

Changes in tensile strength, elasticity, and absolute elongation of polymers, metals and fabrics	± 2% of measured value
Surface deterioration, fungal growth, and contamination	as specified by the appropriate standards
Locating surface and sub-surface flaws in the materials	as specified by the appropriate standards
Thickness, length, width, depth, inside diameter, outside diameter, and other physical dimensions of the test material	± 0.02 mm, ± 0.1% of measurement
Precise weight of test materials	± 0.1% of measured value
Changes in permeability of fabrics and packaging materials	± 5% of measured value
Inorganic materials such as corrosion products	as specified by the appropriate standards
Determining chemical changes in surface of organic materials	as specified by the appropriate standards

3 REQUIRED TEST CONDITIONS

3.1 Pretest Preparation

a. Establish scope and objective(s) of exposure test. For example,

exposure tests may be planned to permit reporting:

(1) Changes in the physical properties of the material after a specified exposure time;

(2) Exposure time to the occurrence of a specified physical change in the material or of a specific event, such as the accumulation of a specified amount of solar radiation;

(3) Degradation profile, namely a record of a series of measurements of changes in physical characteristics after specified exposure periods.

b. Select exposure site(s) and mode(s) of exposure and determine the physical characteristics of the material to be monitored and measured. Selection of the exposure site(s) and mode(s) should be made on the basis of the expected environmental conditions under which the test material is intended to be used. While selecting the exposure site(s) consider the most severe, yet realistic, natural environment available to increase the chances of detecting material deterioration. Selection of physical characteristics to be measured should be based on the expected end use of the material.

c. Establish fixed procedures for pre[illegible]ring, conditioning, and cleaning of the material specimens. The procedures will vary with materials but must be uniform to provide comparative results.

d. Establish laboratory methods and procedures for measurement of material characteristics. When available, standard methods and procedures should be employed, such as Federal Test Method standards or ASTM standards.

e. Determine required instrumentation and its accuracy for measurement of material characteristics in accordance with (IAW) selected methods and procedures.

f. Design data collection sheet(s) for collection of laboratory test data.

g. Establish scoring standards or systems for application during visual inspections of the exposed material samples. Appendix E includes eight references as guides for visual evaluation.[1-8***]

h. Establish exposure test period. Dura[illegible]on of exposure is determined by the requirement of the individual test and the material under test. For example, materials such as ceramics deteriorate slowly over a period of years while carbon steel might rust through within eight weeks.

i. Establish a field inspection schedule and a sample retrieval schedule. An appropriate retrieval schedule is critical to the test. The

***Superscript numbers correspond to those in Appendix E, References.

schedule is determined by the severity of the exposure site, the degradation characteristics of the material, test duration, and test objectives. The following sample retrieval schedules are based on experience of material exposure at TTS sites and are intended for general guidance only.

Material	Average Exposure Time	Typical Retrieval Schedule
Carbon Steel (thickness, 0.25 mm)	8 weeks	Weekly
Cotton Fabric	1 year	Biweekly for first 8 weeks; monthly thereafter.
Plastics (polyvinyl chloride and nylon)	1 year	Biweekly for first 8 weeks; monthly thereafter
Latex (natural rubber)	3 months	Daily for first 3 weeks, weekly thereafter

j Estimate the total sample size of material required to meet the test objective Estimation of the sample size should be based on the test requirements, exposure test length, retrieval schedule, type of laboratory test (destructive/nondestructive), repeatability of measurement techniques, expected material deterioration pattern, and prior knowledge of material homogeneity The sample size should include a sufficient number of samples to serve as control samples (Paragraph 3 3) A statistician and materials engineer should be consulted for assistance in estimating the required sample size This is a critical step in test planning because an insufficient sample size will jeopardize meeting test objectives If test material is available during the test planning phase, procedures at paragraph 3 3 b should be performed at this time

k Establish the experimental design and statistical analyses proposed for addressing the objectives of the exposure test

l Prepare a test operations checklist using the checklist provided in Appendix A as a guide The test operations checklist should cover specifics for the test material and test milestones

3 1 1 Facilities

a Exposure Site Measure and record appropriate environmental site parameters Install exposure rack(s) The area beneath the exposure racks should be typical of the ground cover of the site or as specified in the test plan

b Meteorological Site Install selected instrumentation for measurement of climatological data at the meteorological site, if feasible and required Historical climatological data may be sufficient to characterize meteorological conditions for long term exposure programs

c Exposure Racks The design of the exposure racks (Figure 1) depends on the size and characterization of the test material. Racks and associated hardware should be constructed of materials that are highly resistant to corrosion. Aluminum Alloy No. 6061-T6 and Monel[tm] are recommended as construction materials. Generally the racks should be designed to position the exposed surfaces of the material specimens at an angle of 30 degrees to the horizontal, facing south or east. For some materials, other orientations, such as vertical or horizontal, may be required. The exposure rack should not normally constitute a backing for the specimens. The rack should be designed that the lowest specimens positioned on the rack are exposed at a minimum height of 115 cm above the ground level, as shown in the figure below, unless otherwise dictated by the expected use of the test material.

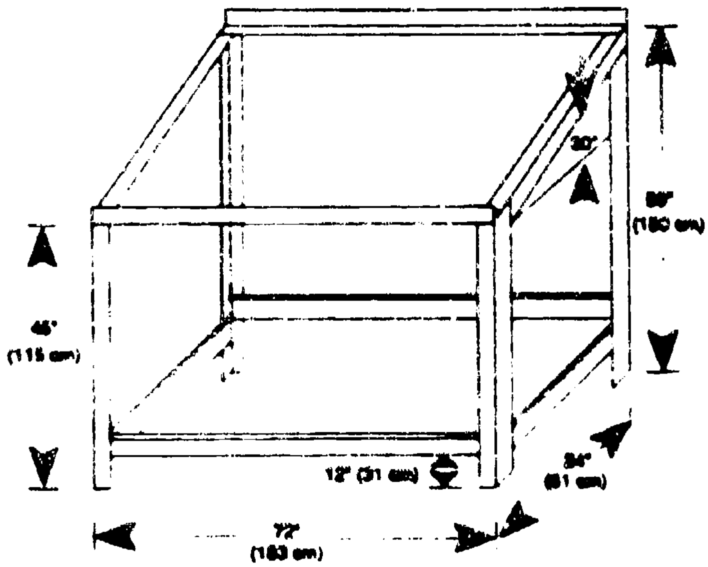

Figure 1 Typical thirty degree exposure rack (rack may be 45 degrees) (Frame material is slotted aluminum angles, approximately 1 1/2 (3 81 cm) by 2 1/2 (6 35 cm) inches, 0.1 (0.25 cm) inches thick.)

d Sample Holders Sample holders should be constructed of an inert material, such as ceramic insulators, aluminum extruded shapes, and plexiglass strips. The sample holders should be designed so that the specimens cannot shift position, yet not be constrained (i.e., be free to expand or contract with thermal changes, to swell from moisture absorption or to shrink because of plasticizer loss). The geometric shape, expected static or dynamic stress use-conditions, physical size, weight, flexibility, and resistance to air flow of the specimens must be considered in the selection of the specimen holders.

Unless specified by the design, the specimen holder should not constitute a backing for the portion of the material to be evaluated.

3.1.2 Instrumentation.

Ensure that and laboratory instruments are calibrated IAW Army Regulation (AR) 750-25[9].

3.1.3 Test Specimens.

a. Test specimens should be procured from the same material lot to optimize homogeneity. The specimens should be prepared and conditioned identically IAW selected procedures (Paragraph 3.1.c).

b. Exposure test specimens may be of any size or shape that can be mounted in a holder directly applied to the racks or as specified by the appropriate test design. The specimens must be of sufficient size so that an appropriate number of suitable specimens may be cut for evaluation. Exposure test specimens should be large enough so that mounting edges can be removed if test results would otherwise be affected.

c. Normally, all materials of unknown end-use application will be exposed in an unbacked condition. When conditions of use are known, the specimen exposed will be displayed in a manner that conforms to the proposed use mode. Backing may be necessary to simulate the proposed use mode. The effect of backing is highly significant and may contribute to the degradation as a function of reflectance and heat absorption. Backing shall be used only to simulate an end-use system rather than as a standard mounting method.

d. All test specimens should be marked with appropriate identification, which must remain legible throughout the exposure period. The rack itself and the position on the rack should be identified. After all specimens are placed on the racks, the test officer should have a detailed sketch or photographic record of the completed rack with all the appropriate markings and identifications.

e. The specimens to be removed after each retrieval interval should be determined before exposure. These specimens should be exposed randomly on different racks to ensure a representative exposure.

f. Packaging is an important factor to be considered before exposing the material. The packaging method should not damage or alter any properties of the specimens while transporting the retrieved specimens back to the laboratories for detailed analysis. Preferably, each specimen should be wrapped individually in an inert envelope, such as paper or plastic. In cases where specimen surfaces are to be examined, soft padded tissue should be used to wrap the specimens. Plastic bags may be sealed as appropriate. Desiccant packs must be used if the material is subject to degradation by humidity. Shipping of specimens should be by the fastest method available.

3.2 Environmental Impact Assessment

a. In compliance with the National Environmental Policy Act (NEPA), the Department of the Army (DA) requires that a life cycle environmental document (LCED) be prepared and that potential environmental impacts be assessed at the earliest practicable stage in the planning process of all tests. Proposed testing at U.S. Army Test and Evaluation Command (TECOM) facilities shall also be assessed for environmental impact. An appropriate Record of Environmental Consideration (REC) is required for all tests. When a proposed action may significantly affect the quality of the environment, is highly environmentally controversial, or is expected to evoke litigation based on environmental issues, a detailed environmental impact statement (EIS) shall be prepared and evaluated IAW NEPA processes. Before the test begins, the project officer shall ensure that an LCED, a REC, and an EIS, or other appropriate documentation has been received and understood

3.3 Test Controls and Limitations.

There are basically two types of control samples: aged and unaged.

a. Unaged control specimens are those material specimens tested prior to any storage or exposure. The resulting test data are used as baseline data (zero time on the performance versus exposure time graphs) and for confirmation of the previous assumption of the degree of sample homogeneity (Paragraph 3.1.j) used for estimating the total sample size required for the exposure test. The size of the sample allocated to this control group should be determined by a statistician experienced in experimental design. Based on the test results of the unaged control samples, modification of the specimen retrieval schedule or changes to the exposed sample size(s) may be required for achievement of the test objectives.

b. Aged control specimens are those material specimens stored at controlled standard conditions of 23$\pm$1°C with 50$\pm$2 percent relative humidity and covered with inert wrapping to exclude light exposure, unless otherwise specified by test requirements. These samples are removed periodically from controlled storage and are tested in the laboratory along with exposed samples. Test data are used to identify the occurrence of nontropic deterioration effects and systematic errors in laboratory test procedures. Sufficient material specimens should be allocated to this control group to obtain statistically significant test results. A statistician should be consulted for estimation of the required sample size. Aged control samples are also used for comparison purposes during field inspection of the exposed samples

3.4 Data Required

a. Description of exposure site(s) and mode(s) to include

(1) Soil (type).

(2) Vegetation (type, stem size, stem spacing, and canopy height);

(3) Ground cover in immediate vicinity of exposure racks (type); and

(4) Slope of site (degrees)

b. Physical location of meteorological facility relative to test site(s).

c. Description of exposure rack and sample holder construction.

d. Orientation of exposure rack(s).

e. Method of mounting specimens

f. Record of material specimen layout on exposure racks.

g. Description of material specimens including photographs

h. Description of specimen conditioning and cleaning procedures.

i. Identification of laboratory test(s) to evaluate material deterioration.

j. Identification of scoring standards for visual inspections

k. Results of laboratory tests of control specimens (baseline data)

l. Exposure test period.

m. Total sample size and allocation of specimens to control and exposure site(s)

n. Field inspection and specimen retrieval schedules

4. TEST PROCEDURES.

4.1 Procedures

a. Install specimens on exposure racks IAW the planned layout (Paragraph 3.1.3 d)

NOTE. Some kinds of sample materials are sensitive to contamination by skin contact. For such materials, it is important to handle only with suitable gloves, such as lint-free cotton, plastic, or rubber. This is more of a requirement on initial emplacement than on retrieval

b. Inspect the exposed specimens IAW the field inspection schedule (Paragraph 3.1.i). Record data on Inspection Data Sheet(s), as shown in

Appendix A. During field inspection, exercise caution in inspecting the specimens. They should not be disturbed unless specified by the test design.

c. Retrieve specimens IAW the retrieval schedule (Paragraph 3.1.1). Specimens should be packaged IAW established packing instruction (Paragraph 3.1.3.f). Transport specimens to the laboratory facility expeditiously.

d. Perform laboratory test on the retrieved specimens to determine changes in their physical properties. Perform laboratory tests concurrently on specimens from the aged control group. Record data on inspection data sheets.

e. Compile and analyze test results.

f. When appropriate, adjust the field inspection schedule and specimen retrieval schedule as data are compiled and analyzed to obtain meaningful test results or to reduce test costs. Some exposure sites may be more or less severe to the specific material under test than was originally estimated.

4.2 Test Controls and Limitations.

a. Ensure that all sensors, recorders, and instrumentation are in a current state of calibration.

b. Ensure that clean plastic gloves are worn at all times when mounting and removing specimens if so specified

c. Perform periodic inspections of the exposure site(s) to ensure materials are properly exposed IAW test design.

d. Procure test sample material from the same lot to optimize sample homogeneity.

e. Provide for unaged and aged control samples (Paragraph 3.3).

f. Utilize randomization techniques for the following actions (consult a statistician for proper randomization procedures):

(1) Sample selection from material lot.

(2) Specimen allocation (control and exposed samples).

(3) Specimen emplacement on exposure rack(s).

(4) Specimen retrieval from exposure rack(s).

(5) Laboratory testing of specimens (control and exposed samples).

4.3 Data Required.

a. Daily Meteorological Data:

(1) Ambient temperature (minimum, maximum, average) in °C.

(2) Relative humidity (minimum, maximum, average) in percent.

(3) Wind speed (minimum, maximum, average), as required in m/sec.

(4) Wind direction (hourly or as required) in degrees.

(5) Solar radiation (total, horizontal/vertical, wavelength/intensity) in J/m^2.

(6) Rainfall (total and intensity), as required in mm.

(7) Saltfall (total), as required in $(mg[Cl^-]/(m^2 \cdot day))$.

(8) Other air contaminants, as required.

NOTE: Historical climatological data may be sufficient to characterize meteorological conditions for long term exposure programs.

b. Field inspection data for each specimen IAW Inspection Data Sheet (Appendix A).

c. Laboratory test data for each specimen (measurements of physical properties of materials).

d. Duration, location, and dates of exposure for each specimen.

e. Presence, extent, and identification of biological growth on the exposed specimens.

f. Material surface deterioration observed visually and under the microscope.

5. DATA REDUCTION AND PRESENTATION.

a. Present the data outlined in paragraphs 3.4 and 4.3 in narrative, tabular or chart format, as appropriate.

b. Compute the sample means and standard deviations of the measured physical properties of the materials and tabulate by exposure site, mode and exposure times.

c. Perform appropriate statistical tests to determine significance of changes in the physical properties of exposed material.

d Develop graphs and display photographs for significantly different groups of data to show changes of material properties versus exposure times

e Analyze the data as required to determine whether observed changes in material properties are statistically related to specific environmental conditions.

APPENDIX A SAMPLE TEST OPERATIONS CHECKLIST AND SAMPLE TEST INSPECTION DATA SHEET

Sample Test Operations Checklist

Item	Yes	No	NA
1 Scope and objectives of exposure test established?			
2 Exposure site(s) and mode(s) selected?			
3 Methods and procedures selected for measurement of physical properties of materials?			
4. Scoring standards selected for visual inspections?			
5. Field and laboratory instruments with required accuracy procured?			
6. Length of exposure test and sample size determined?			
7 Field inspection schedule established?			
8. Sample retrieval schedule establish?			
9 Baseline data (control samples, paragraph 3.3) collected and analyzed?			
10. Exposure rack(s) and sample holder(s) constructed?			
11. Meteorological site established?			
12. Required preparatory data (paragraph 3.4) recorded?			
13. Material samples emplaced at exposure site(s)?			
14. Test milestones completed? (List test milestones by date, check off as complicated.)			
15. All modifications to initial test design documented?			
16. Required test data (paragraph 4.3) recorded?			

Sample Test Inspection Data Sheet

PROJECT NO ______________________________
SITE ______________________________
DATE ______________________________
WEATHER CONDITION ______________________________
INSPECTOR ______________________________
SPECIMEN NO: ______________ RACK NO: ______________
DESCRIPTION OF SPECIMEN: ______________________________
____

1. General Appearance: ______________________________

   a. Surface nature (describe): ______________________________

   b. Surface damage: (If yes, type of damage) Yes____ No____
      Broken? Yes____ No____
      Cracks? Yes____ No____
      Scoring? Yes____ No____
      Crazing? Yes____ No____
      % of Damage: ______________________________

   c. Color: Compare exposed specimen with aged control samples and describe differences: ______________ If new color, identify using Munsell Color Guide: ______________
      ____

      Fading: Yes____ No____

   d. Is sample:
      Transparent? Yes____ No____
      Translucent? Yes____ No____
      Opaque? Yes____ No____

   e. Appearance: Glossy______ Dull______

2. Debris (any foreign matter on sample): Yes____ No____

   a. Percent top surface coverage: ______________________________

   b. Percent bottom surface coverage: ______________________________

   c. Color of: ______________________________

   d. Shape of: ______________________________

   e. Imbedded in material: Yes____ No____
      If no, is it loose? Yes____ No____
      If yes, give depth:______ % Coverage______

f. Identify nature of debris (use of microscope is recommended):

Salts	Yes_____ No_____
Corrosion products	Yes_____ No_____
Soil	Yes_____ No_____
Plant exudates	Yes_____ No_____
Seeds	Yes_____ No_____
Pollen	Yes_____ No_____
Spores	Yes_____ No_____
Algae	Yes_____ No_____
Insect eggs	Yes_____ No_____
Other (Identify)	Yes_____ No_____

g. Collect debris for laboratory analyses.

3. Surface Temperature (if required) ____________(time taken):______________

4. Corrosion:
Color(s) (describe):____
Texture (describe):____
Percent top surface coverage(s):__________________________________
Percent bottom surface coverage(s):_______________________________
Location(s) (describe--use photographs or line drawing for clarity):______
____
____

5. Condition:

a. Is the specimen on the rack? Yes_____ No_____
If no, is it on the ground? Yes_____ No_____
(identify) ____
If no, is it missing? Yes_____ No_____
If missing, explain:____

b. Is the specimen damaged? Yes_____ No_____
If yes, by what and to what extent (describe):_____________________
____

6. Other Comments (for example, changes in dimensions because of stretching, swelling or shrinking):____
____

APPENDIX B. IMPORTANCE OF ENVIRONMENTAL PARAMETERS

1. Temperature: The rate of chemical reactions increases with temperature. Many microorganisms exhibit maximum growth when temperatures are between 24 and 36°C. Air and surface temperature measurements should be made if the study is designed to develop cause-effect relations.

2. Humidity. Condensation becomes a problem when the relative humidity approaches 100 percent. Water as vapor, can diffuse into almost any container through pinhole or cracks larger than 0.001 microns (μ) and condense there. Water helps deteriorate materials by serving as a:

growth medium for bacteria, fungi and other microorganisms;

transport medium for chemicals,

medium for chemical reaction;

hydration agent for dry materials, causing them to swell.

3. Rainfall. Tropical rainfall is usually a heavy downpour of a relatively short duration. Two important effects on materials are as follows: thermal shock due to rapid cooling caused by water on hot surfaces; and wetting of surfaces, thus initiating corrosion processes. Rainwater normally contains dissolved salts and is saturated with oxygen. This water provides an electrolytic path for corrosion propagation.

4. Vegetation. Some types of vegetation exude tannins, sugars, and other natural plant products that may support microbial growth and corrosion processes.

5. Solar Radiation (to include ultraviolet radiation). Radiation can damage exposed samples causing cross linking and changes in polymeric structure and color. Solar radiation may damage heat sensitive items and cause sublimation of polymers and solvents.

6. Soil Type: Soil chemistry and surface water influence, moisture absorption, insect infestation, rot, and corrosion processes of materials used or stored near ground level.

7. Wind Direction and Speed: Wind direction and intensity will influence the amount of particulates that impinge on the test material. At coastal sites, moisture and salt are also transported by winds.

8. Salt Air. Airborne salt will greatly increase the corrosion of metals, especially galvanic corrosion. Sites with heavy saltfall exhibit rapid corrosion rates.

9. Microbial Activity: Microbial activity is important whenever micro-organisms use the exposed sample as a nutrition source or when the metabolic products are detrimental to the material.

10. Insect Fauna: Exposure items, in many instances, serve as food and as a habitat for a variety of insects. Metabolic waste from these insects may damage the exposure items through the action of organic acids or by acting as a substrate for microbial attack.

APPENDIX C. DESCRIPTION OF USATTS EXPOSURE SITES

1. U.S. Army Tropic Test Site (TTS) has exposure sites on the Atlantic and Pacific sides of the Panama Isthmus. A description is given of the severity of several exposure sites for selected materials in the USATTC report, Determination of Optimum Tropic Storage and Exposure Sites.[1] The climate of the TTS sites is classified as either constant high humidity or variable high humidity by AR 70-38.[2] Additional exposure testing data may be found in USATTC report, Materiel Testing in the Tropics.[3]

2. On the Atlantic side, there are four atmospheric exposure sites. All are located on Fort Sherman.

Sites	Grid Coordinates
Fort Sherman Breakwater Exposure	15603614
Fort Sherman Coastal Exposure	15203596
Fort Sherman Open Exposure	14803484
Fort Sherman Forest Exposure	14603113

a. The Breakwater Exposure site is located on the west breakwater at the northern entrance of the Panama Canal on Toro Point. The area is barren, with sparse vegetation. Wind blows continuously from the north. There is considerable salt spray because of the combined effect of continuous wave action and wind. The site is open with no shade and is 84 by 4.5 meters. It has stands and panel racks of Monel and additional space to accommodate more racks and specimens. It is the most aggressive natural atmospheric corrosion site in the world.[4]

b. The Coastal Exposure Site is located about 500 meters west of the Breakwater Site, 50 meters from the water line, and protected by a coral reef, which greatly reduces wave action and makes atmospheric saltfall more typical

[1]Sprouse, J.F., M.D. Neptune, and J.C. Bryan, Determination of Optimum Tropic Storage and Exposure Sites, Report II, Empirical Data. Canal Zone, U.S. Army Tropic Test Center, TECOM Project No. 9-CO-009-000-006, AD A005017, USATTC Report No. 7403001, March 1974.

[2]Army Regulation (AR)-70-38, Research, Development, Test, and Evaluation of Materiel for Extreme Climatic Condition, 1 August 1979.

[3]Materiel Testing in the Tropics, U.S. Army Tropic Test Center, TECOM Project No. 9-CD-150-000-009, USATTC Report No. 790401, April 1979.

[4]Downs, George F. III and Earl A. Baker, Comparative Corrosion Evaluation: Fort Sherman, Panama, and Kure Beach, North Carolina, U.S. Army Tropic Test Center, TECOM Project No. 7-CO-R87-TTO-003, USATTC Report No. 891001, October 1989.

of other marine exposure sites. The fenced area is 12 by 20 meters, largely coral soil, covered by grass. There is no shade. Aluminum racks and exposure cabinets are available at this site. Although substantially less aggressive than the Breakwater Site, continuing high humidity, warm temperatures and frequent wetting and drying combine to make this site more aggressive than most other marine atmospheric corrosion sites.[5]

c. The Open Exposure site, 60 by 30 meters, is about 1.6 kilometers inland. The atmospheric saltfall is much less than at the Coastal or Breakwater sites.[6] The site floor is covered mostly by grass and there is no vegetation to shade the exposure racks. During the rainy season, the water table is at or near ground level, resulting in very high humidity near the surface. Commercial electric power is available.

d. The Forest Exposure site is located in a tropical moist forest. The forest canopy covers the site completely and the trees are considered mature. The relative humidity at this site remains fairly constant near 95 percent during the wet season (mid-March to mid-December). Little sunlight reaches the forest floor and the atmospheric saltfall is low. This site should be used for exposure of noncritical materials because it is unguarded, and unfenced. Alternating current (AC) power is not available.

3. On the Pacific side of the Isthmus, TTS has two sites in Fort Clayton and one site in Rodman Naval Station.

Sites	Grid Coordinates
Fort Clayton General Purpose Test Area	55609850
Fort Clayton Multipurpose Test Area	58129523
Rodman Naval Station Munitions Surveillance Site	52479160

a. The General Purpose Test Area has a variety of different micro-environments because of its relatively large area. They differ from each other, such as under canopy, in the open, on a creek, on a slope, grasslands, etc. This test area is not secured and is currently only in use for tests of termite insecticides on treated stakes. Because of frequent intrusions by local nationals and troops in training, there is no guarantee or expectation of security of any items left in the area unless they are under constant surveillance. Also because of its relatively large amount of grassland, precautions against fire must be taken during the late dry season (mid-January to mid-April).

[5]Ibid.

[6]Ibid.

[7]Holdridge, L.R., et al., Forest Environments in Tropical Life Zone. A Pilot Study. London: Pergamon Press, 1971.

b. The Multipurpose Test Area was formerly used primarily to test collapsible fabric fuel tanks. The site consists of a secured fenced area of 17 hectares. Temporary office, storage, and maintenance building space is provided within the secure area. The site is characterized by high solar radiation and low saltfall. Vegetation ranges from tropical moist forest to grass covered. Berms are available for fuel tank testing and racks and cages can be erected for other exposure testing. Improved roads reach all areas and structures.

c. The Munitions Surveillance site is a secured area and is used to expose ammunition, explosives and "sensitive" items. TTS has four cages of which three have paved floors. The two larger cages have metal roofing. Bunkers and other magazines can also be made available by the Ammunition Supply Point (ASP). Most of the surrounding area is covered by vegetation, including mature tropical moist forest and grassland.

APPENDIX D. ABBREVIATIONS

AC - alternating current

AR - Army Regulation

ASP - Ammunition Supply Point

ASTM - American Society for Testing and Materials

DA - Department of the Army

EIS - environmental impact statement

IAW - in accordance with

LCED - life cycle environmental document

NEPA - National Environmental Policy Act

REC - Record of Environmental Consideration

TECOM - U.S. Army Test and Evaluation Command

TOP - Test Operations Procedure

TTS - U.S. Army Tropic Test Site

APPENDIX E. REFERENCES

1. American Society for Testing and Materials, Philadelphia, Pennsylvania, Standard D660, Standard Method for Evaluating Degree of Checking of Exterior Paints, 1993.

2. American Society for Testing and Materials, Philadelphia, Pennsylvania, Standard D661, Standard Method for Evaluating Degree of Cracking of Exterior Paints, 1993.

3. American Society for Testing and Materials, Philadelphia, Pennsylvania, Standard D662, Standard Test Method for Evaluating Degree of Erosion of Exterior Paints, 1993.

4. American Society for Testing and Materials, Philadelphia, Pennsylvania, Standard D714, Standard Test Method for Evaluating Degree of Blistering of Paints, 1987.

5. American Society for Testing and Materials, Philadelphia, Pennsylvania, Standard D1535, Standard Test Method for Specifying Color by the Munsell System, 1989

6. American Society for Testing and Materials, Philadelphia, Pennsylvania, Standard D1654, Standard Method for Evaluation of Painted or Coated Specimens Subjected to Corrosive Environments, 1992.

7. American Society for Testing and Materials, Philadelphia, Pennsylvania, Standard D4214, Standard Test Method for Evaluating the Degree of Chalking of Exterior Paint Films, 1989.

8. American Society for Testing and Materials, Philadelphia, Pennsylvania, Standard G33, Standard Practice for Recording Data from Atmospheric Corrosion Tests of Metallic-Coated Steel Specimens, 1988.

9. Army Regulation (AR) 750-25, Army Metrology and Calibration System, 25 June 1971.

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